MICRO-DRILLING USING Nd-YAG LASER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
in
Mechanical Engineering

By

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DEPRTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

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CERTIFICATE

This is to certify that the thesis entitled "MICRODRILLING BY LASER" submitted by Mr. Sandip Kumar Bhuyan in partial fulfilment of the requirements for the award of Bachelor of technology Degree in Mechanical Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Prof K.P.Maity Date:13/05/09

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A BSTRACT

Now a days micro drillings have a great use for manufacture of sophisticated items, parts etc.Laser microdrillings give a better aspect ratio than tool micro drillings. Laser micro-hole drilling service provides access to world leading precision hole drilling technology. This service can be used for R&D through to full production. Minimum micro-hole sizes can be as low as 1 micron in thin materials. For micro-holes above 20 microns in, we can use proprietary treppaning technology to generate micro-holes of unsurpassed roundness with controlled taper.Using a variety of IR, visible and UV sources, we select the correct wavelength and pulse duration, develop the laser micro-hole drilling process and produce the parts. Numbers of micro-holes per part can range from one to tens of thousands. Typical quantities of parts range from one-off for R&D, to tens of thousands per month. Microdrills are typically made of either cobalt steel or micrograin tungsten carbide. The steel drills are less expensive and easier to grind but are not as hard or strong as the tungsten carbide drills. The drill point angle is based on the material to be drilled. The normal point angle is 118 degrees and 135 degrees is used for hard materials. The larger included point angle provides more strength at the drill pointdameter. Microdrilling has one major disadvantage because of the drill geometry. Because of the drill point, a flat-bottomed hole can not be produced. If one is attempting to produce cylindrical cavities in a micromold, there must be a relatively thick plating base under the mold material, or the structural substrate of the mold could act as the plating base.

CHAPTER 1:

INTRODUCTION

DEFINITION:

Microdrilling is characterized not just by small drills but also a method for precise rotation of the microdrill and a special drilling cycle. In addition, the walls of a microdrilled hole are among the smoothest surfaces produced by conventional processes. This is largely due to the special drilling cycle called a peck cycle. The smallest microdrills are of the spade type. The drills do not have helical flutes as do conventional drills and this makes chip removal from the hole more difficult. Drills with a diameter of 50 micrometers and larger can be made as twist drills. Drills smaller than this are exclusively of the spade type because of the difficulty in fabricating a twist drill of this size.Microdrills are typically made of either cobalt steel or micrograin tungsten carbide. The steel drills are less expensive and easier to grind but are not as hard or strong as the tungsten carbide drills. The drill point angle is based on the material to be drilled. The normal point angle is 118 degrees and 135 degrees is used for hard materials. The larger included point angle provides more strength at the drill point.Laser micromachining is a very powerful method for the production of micro-parts or micro-features on larger parts. Feature sizes down to 1 micron can be produced in the right circumstances and holes or features of 5 microns and above are routine. Oxford Lasers has a number of state of the art micromachining systems that are available for R&D or sub-contract manufacture. These systems are designed to be flexible so that many different processes can be investigated.The laser systems can be used for micromachining, micro-drilling, micro-cutting, precision machining, fine cutting, microfabrication, ablation studies, MEMS, scribing, etching, marking, engraving and milling. Laser micro machining can often be a more cost-effective alternative to techniques such as micro EDM.In most cases laser micromachining works best if the feature to be produced is less than 1 mm in depth. For example, micro-hole drilling is normally limited to materials less than 1.5 mm thick and aspect ratios less than 30:1. In special circumstances or particular materials, deeper or higher aspect ratio holes can be drilled. Microdrilling has one major disadvantage because of the drill geometry. Because of the drill point, a flat-bottomed hole can not be produced. If one is attempting to produce cylindrical cavities in a micromold, there must be a relatively thick plating base under the mold material, or the structural substrate of the mold could act as the plating base.

The electromagnetic spectrum consists of the complete range of frequencies from radio waves to gamma rays. All electromagnetic radiation consists of photons which are individual quantum packets of energy. For example, a household light bulb emits about 1,000,000,000,000,000,000,000 photons of light per second! In this course we will only concern ourselves with the portion of the electromagnetic spectrum where lasers operate - infared, visible, and ultraviolet radiation.

Name	*Wavelength*
Ultaviolet	100 nm - 400 nm
Visible	400 nm - 750 nm
Near Infared	750 nm - 3000 nm
Far Infared	3000 nm - 1 mm

Einstein was awarded the Nobel Prize for his discovery and interpretation of the formula - E=mc2 - right? Wrong.

He won the Nobel Prize for his explanation of the phenomena referred to as the photoelectric effect. When light (electomagnetic energy) is shined on a metal surface in a vacuum, it may free electrons from that surface. These electrons can be detected as a current flowing in the vacuum to an electrode. The light was not always strong enough to cause this effect, however. When the scientists made the light brighter, no increase in electrons was seen. Only when they changed the color of the light (the wavelength) did they see a change in photoemission of electrons. This was explained by Einstein using a theory that light consists of photons, each with discrete quantum of energy proportional to their wavelength. For an electron to be freed from the metal surface it would need a photon with enough energy to overcome the energy that bound it to the atom. So, making the light brighter would supply more photons, but none would have the energy to free the electron. Light with a shorter wavelength consisted of higher energy photons that could supply the needed energy to free the electron. Now, you ask, "What the heck does this idea of quantum energy have to do with a laser?". Well, with this background under our belts we will continue.

There are many types of lasers available for research, medical, industrial, and commercial uses. Lasers are often described by the kind of lasing medium they use - solid state, gas, excimer, dye, or semiconductor.

- **Solid state** lasers have lasing material distributed in a solid matrix, e.g., the ruby or neodymium-YAG (yttrium aluminum garnet) lasers. The neodymium-YAG laser emits infrared light at 1.064 micrometers.

- **Gas** lasers (helium and helium-neon, HeNe, are the most common gas lasers) have a primary output of a visible red light. CO_2 lasers emit energy in the far-infrared, 10.6 micrometers, and are used for cutting hard materials.

- **Excimer** lasers (the name is derived from the terms *excited* and *dimers*) use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. When electrically stimulated, a pseudomolecule or dimer is produced and when lased, produces light in the ultraviolet range.

- **Dye lasers** use complex organic dyes like rhodamine 6G in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths.

- **Semiconductor** lasers, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, e.g., the writing source in some laser printers or compact disk players.

Lasers are also characterized by the duration of laser emission - continuous wave or pulsed laser. A Q-Switched laser is a pulsed laser which contains a shutter-like device that does not allow emission of laser light until opened. Energy is built-up in a Q-Switched laser and released by opening the device to produce a single, intense laser pulse.

- **CONTINUOUS WAVE** (CW) lasers operate with a stable average beam power. In most higher power systems, one is able to adjust the power. In low power gas lasers, such as HeNe, the power level is fixed by design and performance usually degrades with long term use.

- **SINGLE PULSED** (normal mode) lasers generally have pulse durations of a few hundred microseconds to a few milliseconds. This mode of operation is sometimes referred to as long pulse or normal mode.

- **SINGLE PULSED Q-SWITCHED** lasers are the result of an intracavity delay (Q-switch cell) which allows the laser media to store a maximum of potential energy. Then, under optimum gain conditions, emission occurs in single pulses; typically of 10(-8) second time domain. These pulses will have high peak powers often in the range from 10(6) to 10(9) Watts peak.

- **REPETITIVELY PULSED** or scanning lasers generally involve the operation of pulsed laser performance operating at a fixed (or variable) pulse rates which may range from a few pulses per second to as high as 20,000 pulses per second. The direction of a CW laser can be scanned rapidly using optical scanning systems to produce the equivalent of a repetitively pulsed output at a given location.

- **MODE LOCKED** lasers operate as a result of the resonant modes of the optical cavity which can effect the characteristics of the output beam. When the phases of different frequency modes are synchronized, i.e., "locked together," the different modes will interfere with one another to generate a beat effect. The result is a laser output which is observed as regularly spaced pulsations. Lasers operating in this mode-locked fashion, usually produce a train of regularly spaced pulses, each having a duration of 10(-15) (femto) to 10(-12) (pico) sec. A mode-locked laser can deliver extremely high peak powers than the same laser operating in the Q-switched mode. These pulses will have enormous peak powers often in the range from 10(12) Watts peak.

CHAPTER 2:

LITERATURE SURVEY

LITERATURE:

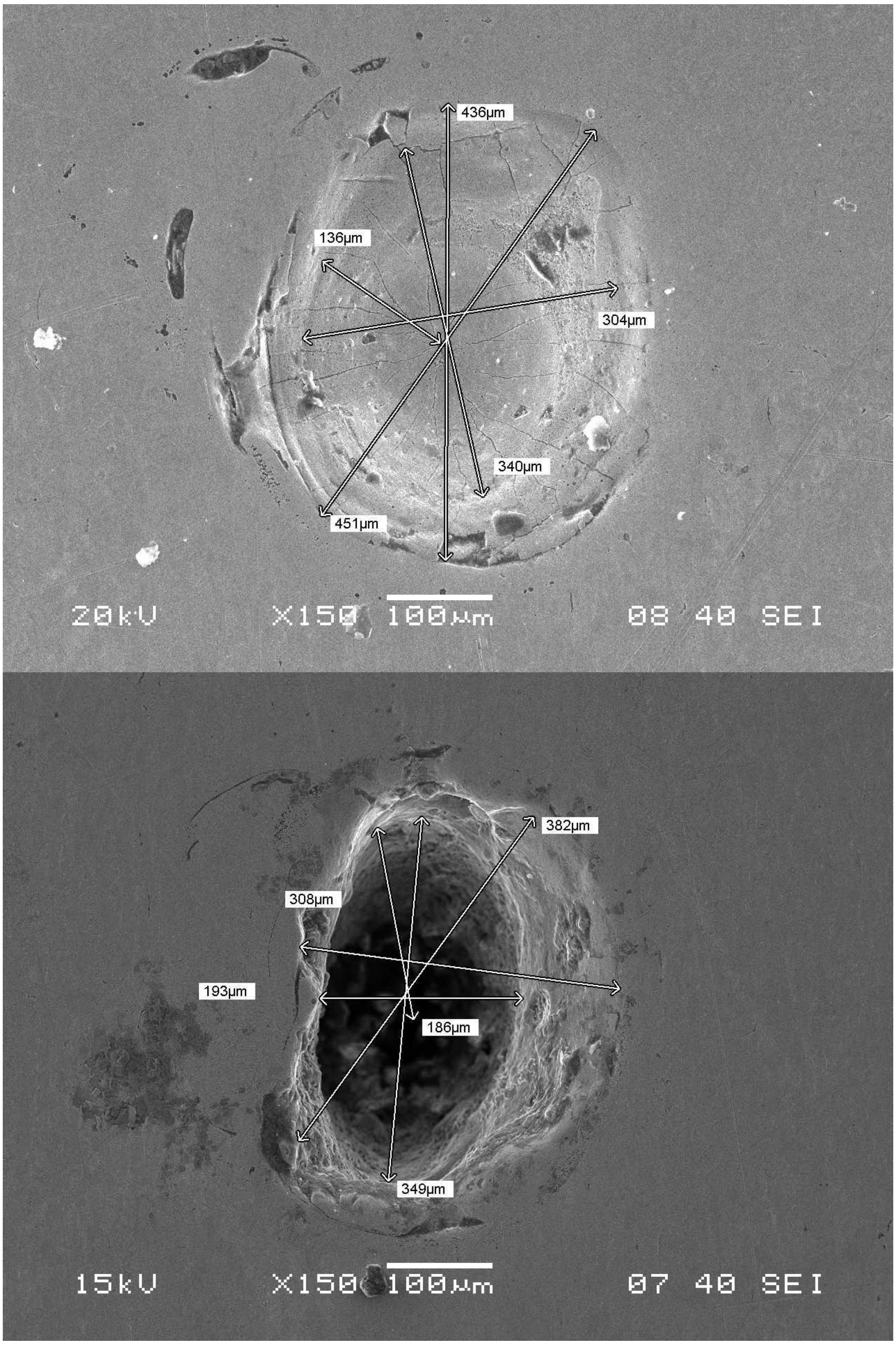
Laser micro drilling is today in some industrial fields of application a well known production process. Lasers can be utilized for drilling in most materials, metal alloys, polymers, ceramics etc. Laser drilling is, however, less applied inindustry than laser cutting and melding. The key reason is the satisfying quality of laser drilling can not be obtained in some application situations. For this reason, recent efforts in laser process development have focused on the optimumselection of the laser beam parameters for increasing the quality. This paper summarizes the effects of processing parameters in CO2-laser micro drilling and describes the results of aparametric investigation including the optimum parameters selection and their influence on the obtained quality of the hole with diameters in the range 0.1~1.0 mm. **B**asic **P**rinciple of **L**aser **B**eam **W**orkpiece **I**nteraction.The thermal effects obtained during laser processing are the foundation of the laser drilling. The basic principle can be described by three different phases, as shown in Fig.1.The first step in the laser drilling process is the absorption of laser radiation by the workpiece. The material is heated by absorbing laser radiation. It is possible to estimate the heatabsorbed at a certain position in the material ifknown. After the incident laser energy is absorbed by the workpiece, the next step in the hole drilling process is the heat flow inside the solid material, leading to the change of state (melting and vaporization) that results in material removal. The absorption of this step is named as Fresnel absorption [1], where the light will be partially absorbed and partially reflected. It results in multiple reflections of part of the light. This will cause high intensity absorption in the bottom region of the hole. With the incident laser energy more increasing, the hole drilling process comes into third step, plasma. The intensity of the laser beam is high in the pulse, resulting in plasma formation especially in the center line and in the bottom of the hole. It should be noted that the multiple reflections will increase the intensity on the hole surface in the bottom. Furthermore, it should be noted that the wall reflections will result in an intensity increase in the center line of the hole in the bottom. Therefore, there is a large plasma formation in the bottom of the hole as long as the hole has not penetrated the material. On the other hand, if the plasma formation is too strong and the plasma is absorbing the laser light, absorption in plasma will take place too high in the hole and the region of the highest pressure will be in the upper part of the hole. This will limit the depth of penetration as in drilling. Formost metals, the plasma absorption is small at the wave length of the ND-laser (1.06_*m*), but large at the wave length of the CO2-laser (10.6_*m*). The fact is that plasma effects are an advantage for CO2-laser drilling [2].

The vaporization of different material relates with the threshold of vaporization in the laser drilling process.

CHAPTER 3:

EXPERIMENT AND ANALYSIS

Drilling is carried out by Nd-YAG laser at different pulse rate ,different power and different air flow.Each point is drilled for 20 seconds.Nine holes are drilled on sample of mild steel.Here the experiment is carried out to produce microdrills with greater efficiency,means we have to minimize the power consumption and time consumption and give the most efficient drills having a greater aspect ratio.By this experiment we have to find out the parameters with which best holes are produced.So the specimen is experimented with Nd-YAG laser with different levels of the parameters for a fixed time .Here parameters are the pulse rate,Air-flow rate and the power needed in watt.Different diameters and depth of the holes are measured for different levels of the parameters.Levels of the parameters means different value of the parameters or factors at which experiments are carried out.T he experiments which is carried out at different levels of different factors or parameters are experimented using minitab software. The sample after experiment is stored in a decicator to protect it from corrosion such that dimensions of the holes made by the laser at different conditions should not be affected. The diameters and depth of the holes are measured using an electron micro-scope in particular conditions in the SEM Lab. The average diameter is calculated from the figures taken by micro-scope. Circulate error and L/D ratio is also calculated. For better efficiency of the drilling the L/D ratio should be maximum and circulate error should be minimum. So we take the help of TAGUCHI method to calculate the levels of the parameters at which better drilling cam be done. As we have drilled nine holes it comes under L-9 orthogonal array of the taguchi method. There are two methods in the mini tab software to calculate the better conditions.One is full factorial method and other one is taguchi method.We take taguchi method for calculation and analysis, because taguchi method deals with man effects only.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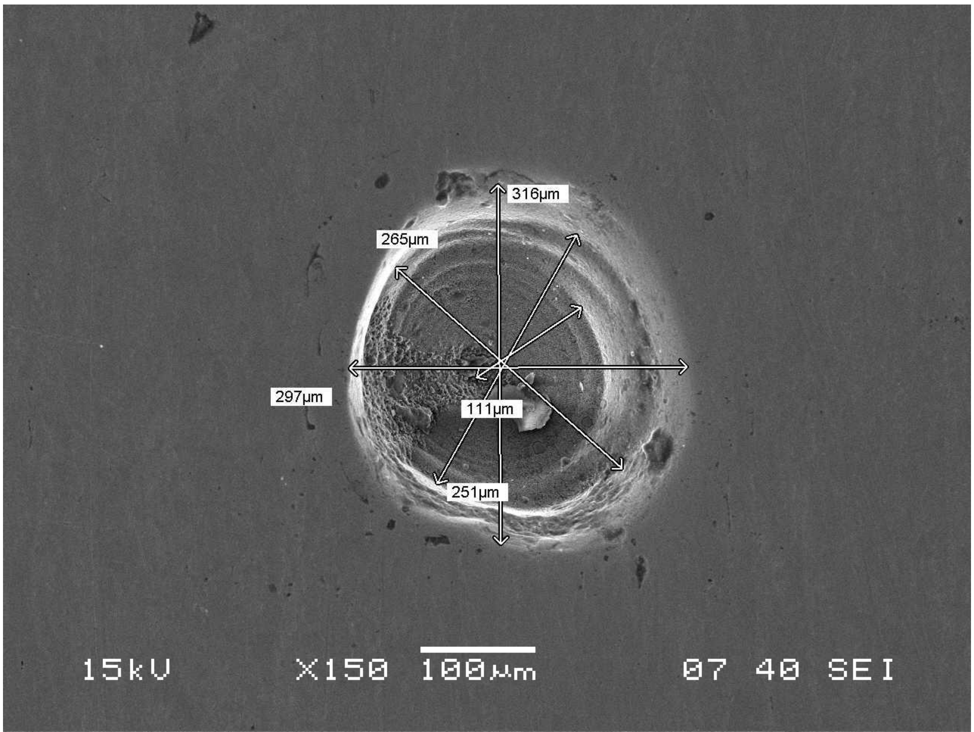
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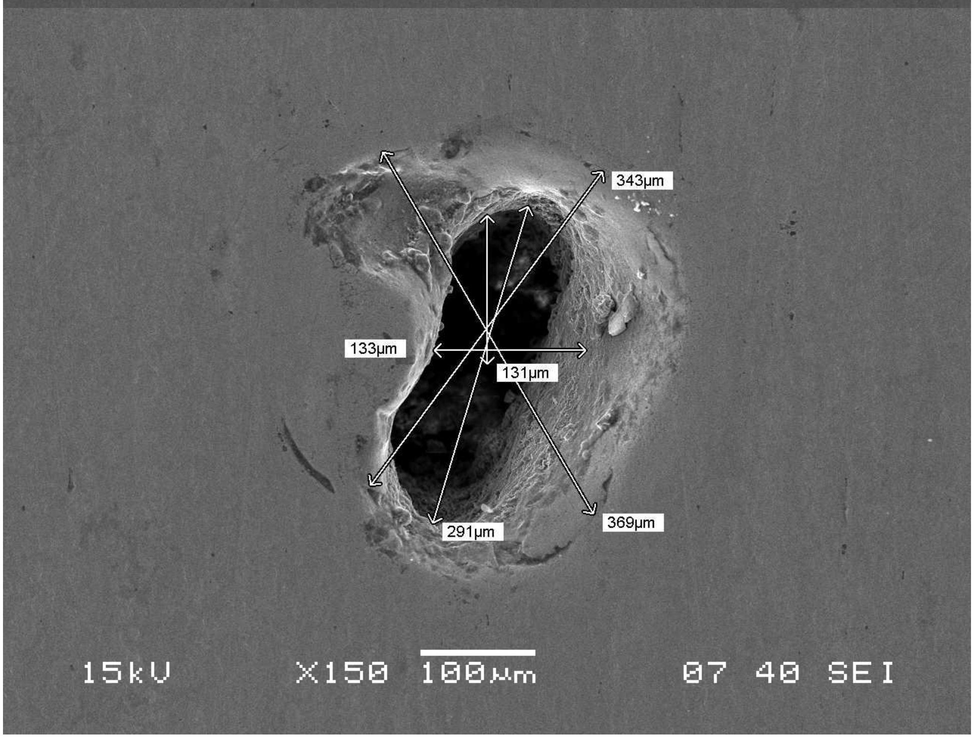
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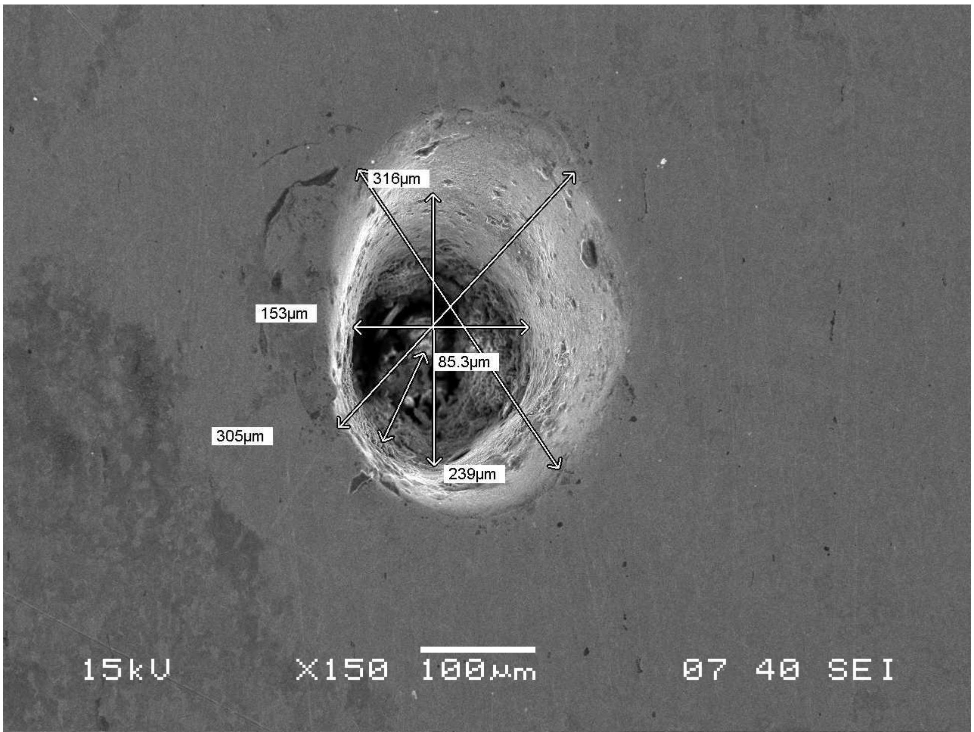
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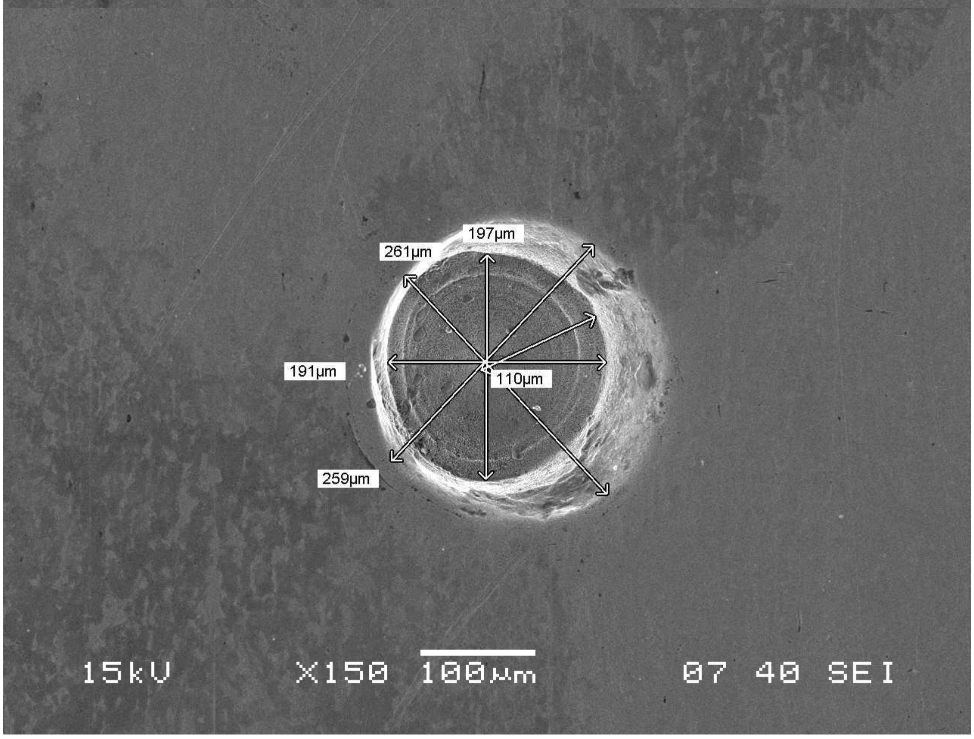
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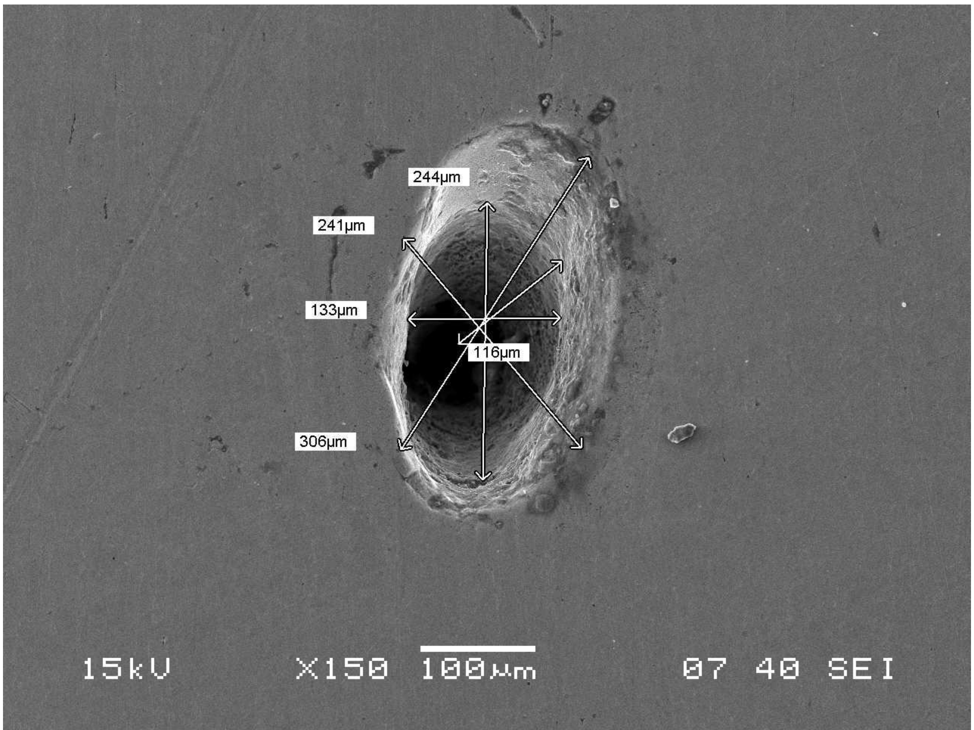
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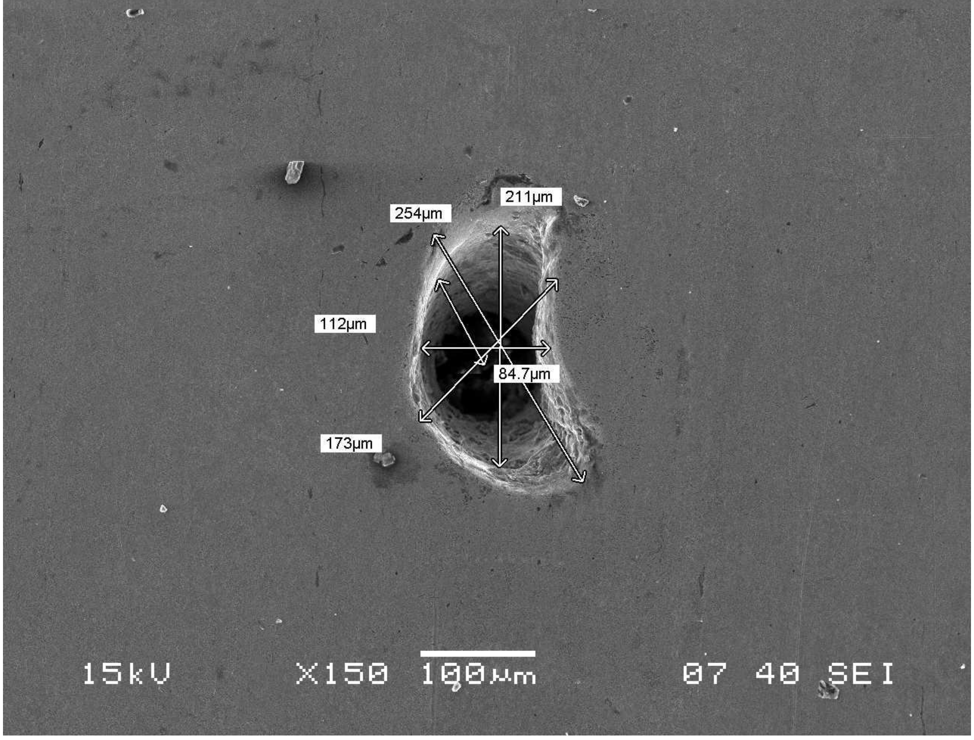
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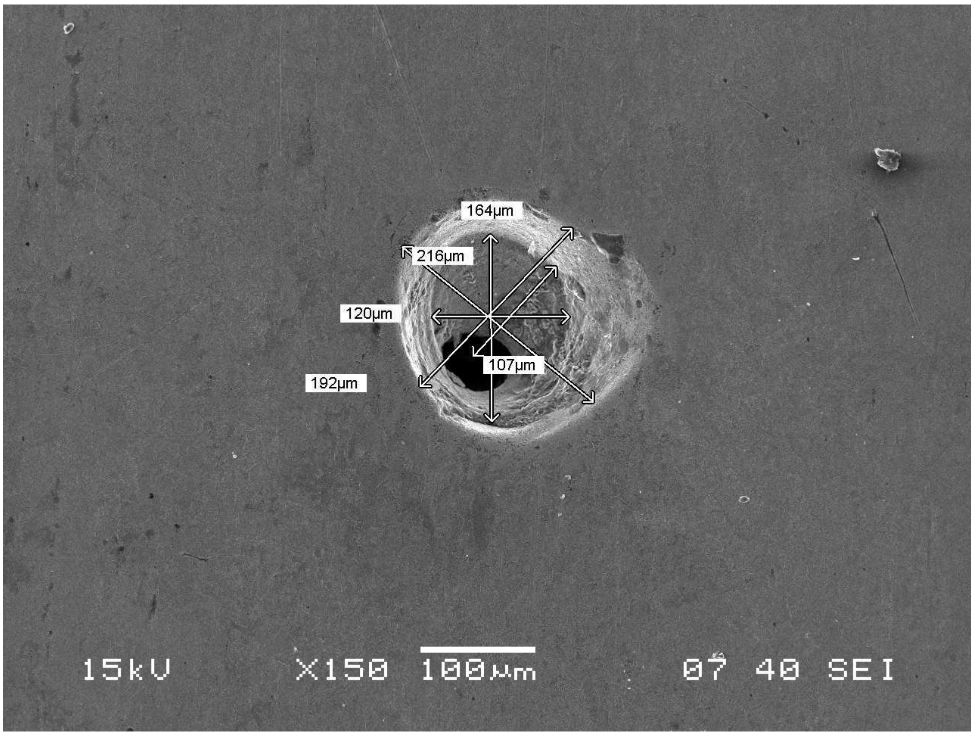
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107µm
192µm
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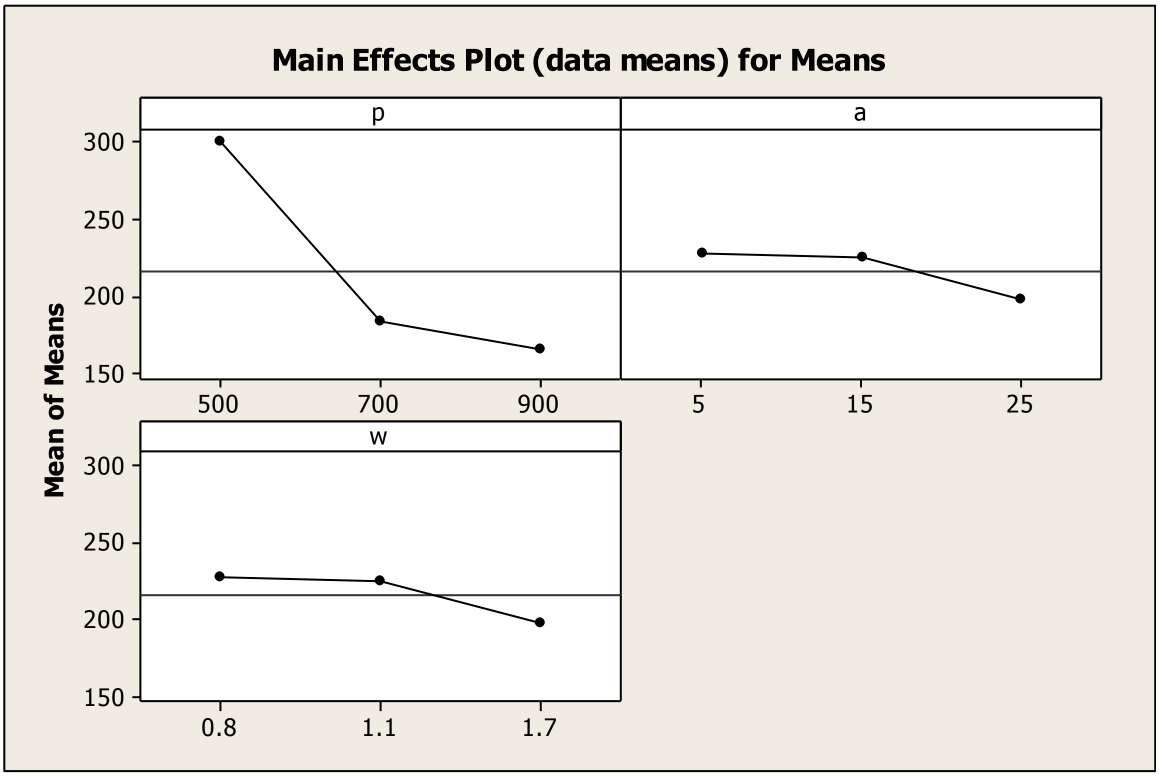
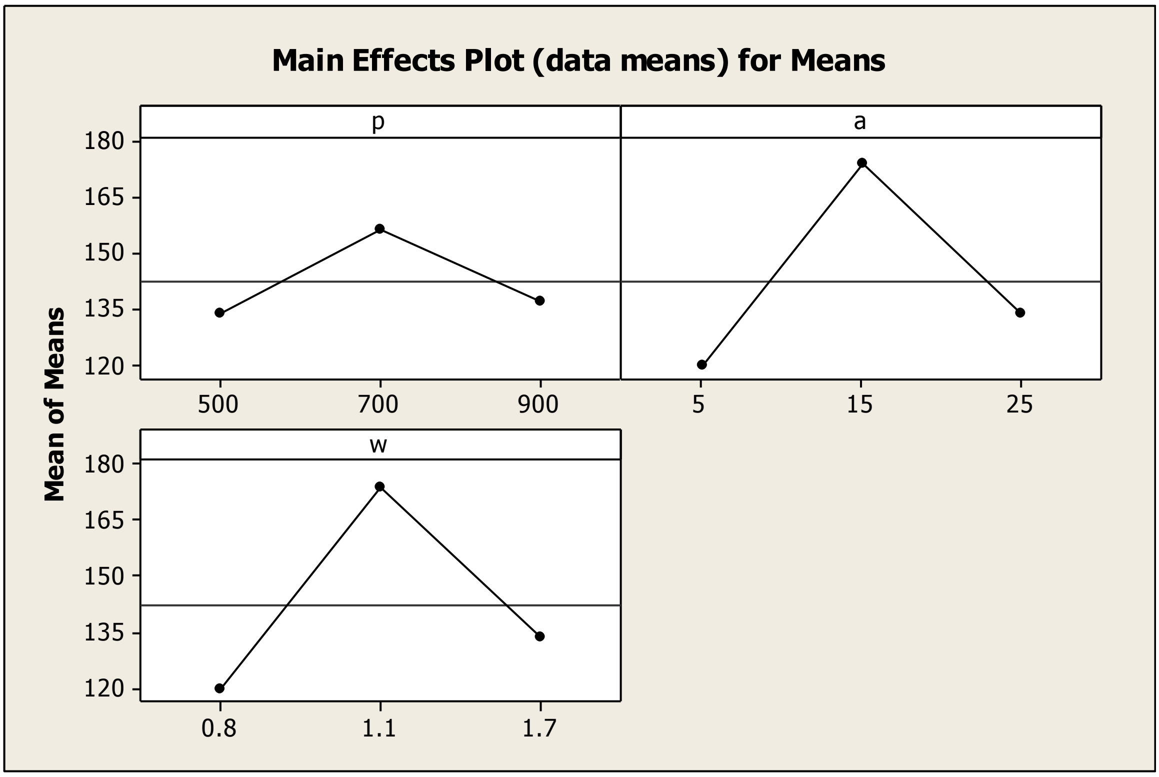

Main Effects Plot (data means) for Means
p
a
w
Mean of Means
300
250
200
150
500 700 900
5 15 25
0.8 1.1 1.7



p	a	w	d	l/d	c	MEAN1	MEAN2
500	5	0.8	322.0	0..42	147	322.0	147
500	15	1.1	321.0	0.58	189	321.0	189
500	25	1.7	258.0	0.43	65	258.0	65
700	15	1.1	212.0	0.6	236	212.0	236
700	25	1.7	146.0	0.34	163	146.0	163
700	5	0.8	194.0	0.56	70	194.0	70
900	25	1.7	188.5	0.6	173	188.5	173
900	5	0.8	165.0	0.5	142	165.0	142
900	15	1.1	142.0	0.75	96	142.0	96

CHAPTER 4:

RESULTS AND DISCUSSION

RESULT AND DISCUSION:

After taking measurement in SEM Lab the average diameter is calculated.Circulate error(maximum dia-minimum diameter) and L/D ratio is also calculated(where ‘L’ is the depth of the hole).The results of the experiment are in the L9 orthogonal array form.Here we put the outputs and factors in the Taguchi orthogonal matrix and study them graphically.Process having maximum L/D ratio and minimum circulate error gives the best drilling.Graphical representation of Taguchi’s L9 method shows that the diameter first decreases,then becomes constant by increasing pulse rate and remains almost constant and then decreases with increasing power supply and air flow rate.So the L/D ratio goes in the opposite way.It first increases,then decreases with increasing levels of parameters.So increasing levels of parameters provides better drilling.

CHAPTER 5:

CONCLUSION

CONCLUSION:

From this experiment we concluded that the experiment are in the L9 orthogonal array form.Here we put the outputs and factors in the Taguchi orthogonal matrix and study them graphically.Process having maximum L/D ratio and minimum circulate error gives the best drilling.Graphical representation of Taguchi’s L9 method shows that the diameter first decreases,then becomes constant by increasing pulse rate and remains almost constant and then decreases with increasing power supply and air flow rate.So the L/D ratio goes in the opposite way.It first increases,then decreases with increasing levels of parameters.So increasing levels of parameters provides better drilling.

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